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(54) Title: CLEARMOLD PHOTODIODE PACKAGE HAVING DIFFRACTIVE/REFRACTIVE OPTICAL SURFACES

(57) Abstract

An image sensor is made up of a photosensor (64) and a packaging means that directs light to the photosensor. For one embodiment, the packaging means is a clearmold package (62) having an optical surface (66) that directs an image onto the photosensor. The optical surface may have either a refractive or diffractive surface that reduces aliasing effects of image capture. The clearmold package may also include a filter to block infrared light.



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CLEARMOLD PHOTODIODE PACKAGE HAVING DIFFRACTIVE/REFRACTIVE OPTICAL SURFACES**BACKGROUND OF THE INVENTION****1. Field of the Invention**

The described invention relates to integrated circuit packaging. More particularly, this invention relates to combining optical functionality with a clearmold package.

2. Description of Related Art

Image sensors are used in cameras for capturing an image. Typically, an image is focused by optics onto an image sensor array. The image sensor array comprises individual photosensors, each of which may have a color filter that responds to a particular color input. The photosensors are situated in an array with color filters arranged in a mosaic pattern to allow replication of the image by sampling particular colors at various locations of the image sensor array and interpolating these colors to other locations of the image sensor array, as is well known.

Figure 1 shows a first prior art image sensor system 5. In this case, optics 10, which may comprise one or more lenses, focus an image to an image sensor array 20. The image sensor array 20 is housed in a package that has a window 22. Image capture output signals are provided by leads 24.

Figure 2 shows another prior art image sensor system 30. In this case, the image sensor comprises optics 32, an infrared (IR) filter 34, and an image sensor array 36. The image sensor array is encapsulated in a mold compound 38, such as those manufactured by Nitto Denko America of Fremont, California, or Dexter Corp of Windsor Locks, Connecticut.

One problem with the prior art systems is that at each surface of the lens, window, or IR filter interface, there is a reflection loss. Ghost images and reduced transmission produced by reflections lower the quality of the image making it to the image sensor array. High quality glass, which is relatively expensive, is typically required for reduced surface blemishes (scratch and dig) especially at the surface nearest the sensor. Coatings can be used to reduce ghost images caused by multiple reflections involving the window, but they must be of extremely high quality (and expense) in order to meet the stringent surface blemish requirements.

Another problem with optical systems that form images on detector arrays that discretely sample images (e.g., charge coupled detector ("CCD") or complementary metal oxide semiconductor ("CMOS") image sensors) is that they produce aliasing effects in the displayed image. An example of aliasing effects is Moiré effects which occur when objects move, change patterns and/or change color relative to the detector array and the

objects' representation on the detector array has dimensions commensurate with the pixel dimensions of the detector array. One solution for eliminating or minimizing aliasing effects is to add a quartz plate in front of the detector array, as shown in Figure 2. The quartz plate blurs and reduces the sharpness of the image just the right amount to minimize such aliasing effects. However, quartz plates are very expensive, virtually costing as much as the lens system.

Other prior art lens systems have attempted to solve aliasing effects by providing anti-aliasing features that are molded onto a lens surface (using aspheric surface profiles). These features introduce spherical aberration to blur the image of a point object. However, this design solution is specific to the image sensor array. If the image sensor array is changed, the lens would have to be changed also.

Additionally, imaging systems built with CCD or CMOS based sensors generally require an infrared (IR) selective filter as part of the optical system. This need arises because the most common semiconductor-based image sensing devices, silicon-based image sensing devices, respond not only to visible light (approximately 380 to 780 nanometers), but also to infrared light in the range of approximately 780 to 1100 nanometers. Without an infrared blocking filter, it is virtually impossible to obtain a high-quality color image due to the combination of visible and IR signals. Monochrome imagers also require an IR selective filter to correctly preserve scene luminance.

Digital imaging systems typically incorporate an IR filter, such as glass or plastic, as part of the optical train, i.e., somewhere in the optical system apart from the image sensing device and either overlying the lens or interposed within other optical elements. The disadvantages of the inclusion of a separate IR selective filter is that it adds an additional component to the total system count, i.e., piece-part count, including additional surfaces (with inherent transmission loss and ghost images). The additional component adds complexity to the imaging system. Further, depending on where the IR selective filter is placed, there is a size consideration that directly affects the cost of the imaging system. The system software and signal processing must also be adjusted to accommodate the color performance characteristics of the IR selective filter. Still further, if the IR selective filter is placed, for example, in front of the lens, the IR selective filter is exposed to the environment, which may damage it through, e.g., moisture or scratching.

SUMMARY OF THE INVENTION

An image sensor is made up of a photosensor and a packaging means that directs light to the photosensor. For one embodiment, the packaging means is a clearmold package having an optical surface that directs an image onto the photosensor. The optical

surface may have either a refractive or diffractive surface that reduces aliasing effects of image capture. The clearmold package may also include a filter to block infrared light.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a first prior art image sensor system having a windowed package.

Figure 2 shows another prior art image sensor system including an image sensor array that is in an encapsulated clearmold package.

Figure 3 shows one embodiment of an image sensor comprising an image sensor array encapsulated within a clearmold package.

Figure 4A illustrates an expanded side view of an anti-alias surface 102 of a lens-clearmold surface.

Figure 4B illustrates another embodiment of an anti-alias surface of a lens-clearmold surface.

Figure 5 shows an example of a refractive lens-clearmold surface.

Figure 6 shows an expanded side view of another example of a diffractive lens-clearmold surface.

Figures 7A and 7B show a diffractive surface that may be used to correct for chromatic aberrations created by other lens elements.

Figures 8A-8C show an example of a binary optic diffractive surface structure. Figure 8A shows an embodiment of a side view of the structure. Figures 8B and 8C show alternate embodiments of top views of the structure.

Figure 9 shows an imaging system incorporating an image sensor according to the invention.

Figure 10 shows a flowchart of one embodiment for creating a clearmold package having an optical surface.

DETAILED DESCRIPTION

A method and apparatus for combining clearmold technology with optical functionality is described to simplify the creation of an imaging system.

Figure 3 shows one embodiment of an image sensor 60 comprising an image sensor array 64 encapsulated within a clearmold package comprising a mold compound such as a plastic epoxy, thermoplastic, or thermoset. The clearmold package is molded to form a lens 62 that focuses light from an image onto the image sensor array 64. The lens 62 can take on a variety of different shapes including spherical and an aspheric

cylinder. A lens-clearmold surface 66 is formed by a mold process that will be explained in more detail later.

By combining the lens into the clearmold package material, reflection losses are reduced because there are fewer surface-to-air interfaces. This reduces the amount of image distortion reaching the image sensor array. Additionally, high precision glass lenses are no longer required, which saves on cost.

Alignment issues are also simplified with the molded lens-clearmold package because, once molded, the lens remains fixed in proper alignment with respect to the image sensor. The lens molded into the clearmold package material need not be the entire optical system though. Because of its proximity to the sensor die (or light modulator), the lens can be what is called a "field flattener lens" working in conjunction with a fixed focus, focusable, or zoom lens that is not part of the clearmold package, as is well known.

Additional optical functionality may also be added via the mold process. For example, diffractive and refractive anti-aliasing structures can be molded into the lens-clearmold surface 66, as is described with respect to Figures 4A-4B, 5, 6, 7A-B, and 8A-C.

Figure 4A illustrates an expanded side view of an anti-alias surface 102 of a lens-clearmold surface. Referring to Figure 4A, the lens element surface 102 includes a radially-symmetric periodic "cosine-like" surface 104 molded on the lens element surface 102. The periodic surface 102 (or microscopic ripple) causes the image of a point to be spread in a controlled manner. The period 106 and depth 108 of the rippled surface are selected to control the size of the blur and the manner in which energy is distributed.

In one embodiment, the radially-symmetric cosine ripple has a constant amplitude and at least two periods across the semi-diameter of the aperture stop 142. In a second embodiment, the cosine ripple has a monotonically decreasing amplitude across the aperture. In a third embodiment, the cosine ripple has a monotonically changing period across the aperture. In yet a fourth embodiment, the cosine ripple has both a monotonically decreasing amplitude and changing period across the aperture. The cosine ripple is created on a tool, typically made out of stainless steel. The lens element is then molded with mold compound which forms the clearmold package including the ripple on the lens-clearmold surface.

Figure 4B illustrates another embodiment of an anti-alias surface of a lens-clearmold surface. In this embodiment, a "puckered" surface 150 is used and includes an array of dimples or "bumps" 152. The array of "bumps" 152 perturbs the wavefront from a point object so that it spreads into a single blur that is insensitive to the relative aperture, object distance, or zoom position.

Figure 5 shows an example of a refractive lens-clearmold surface. In this example, a fresnel lens 160 is formed via the mold process. The fresnel lens may be spherical or an aspheric cylinder. The fresnel lens focuses light to the image sensor array 162.

Figure 6 shows an expanded side view of another example of a diffractive lens-clearmold surface and an image sensor array 172. In this case, a blazed diffraction grating structure 170 is used to reduce aliasing effects. The pitch of the blazed diffraction structure may be varied across the radius of the lens to provide color correction, and the blaze pattern may be varied to add blurring. The blazed diffraction grating may be used to eliminate higher diffractive orders of incoming light from being transmitted, as is well known.

Other lens-clearmold surfaces can also be created for other optical functionality. For example, Figures 7A and 7B show a diffractive kinoform surface that may be used to correct for chromatic aberrations created by other lens elements, as is described in co-pending U.S. Patent application, Serial Number 09/002,905, entitled "Compact Zoom Lens with Diffractive Surface and Anti-Aliasing Feature," assigned to Intel Corporation.

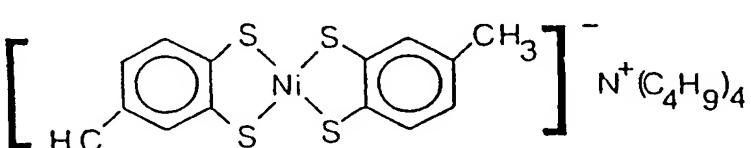
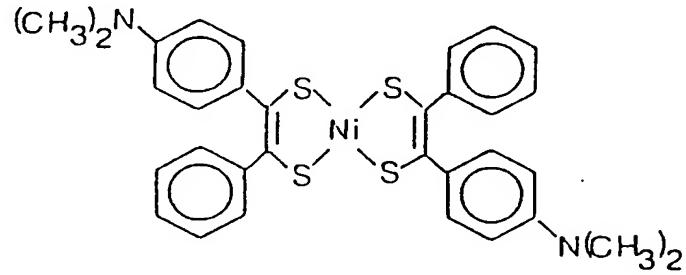
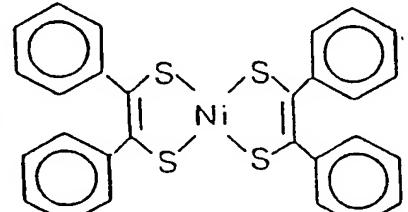
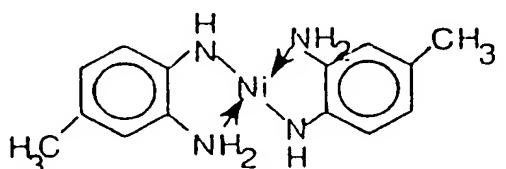
Figure 7A illustrates a front view of an exemplary diffractive surface. Referring to Figure 7A, the diffractive surface includes a plurality of rings 210 that are concentric from the center of an aperture. The rings 210 at the center of the surface are widely spaced apart and as the surface is traversed from the center, the rings are more and more closely spaced together. Figure 7B illustrates a side view of the exemplary diffractive surface 220. As shown in Figure 7B, the diffractive surface 220 includes a center zone 222 and successive annular zones 224. In the embodiment shown, the diffractive surface 220 adds strong negative axial chromatic aberration which offsets a positive axial chromatic aberration of other optical surfaces in the imaging system.

Figures 8A-8C show an example of a binary optic diffractive surface structure. Figure 8A shows a side view of structure. A binary optic diffractive structure comprises a stepped structure that may be arranged in a pseudo-circular arrangement, as shown in Figure 8B, or in an arbitrary height grid in which step structures are implemented in an arbitrary non-symmetric pattern (no radial symmetry), as shown in Figure 8C.

IR Filter

In one embodiment, the clearmold plastic substrate is combined with a dye, such as an organic dye, that selectively filters IR light. There are various methods of making a plastic element selective to IR light, including dispersing the dye throughout a plastic substrate or coating the dye on the plastic substrate. These methods are described in co-pending U.S. patent application Serial Number 09/052,899, entitled "Plastic Light Selective Element for Imaging Applications," and assigned to Intel Corporation. The IR selective dyes include, but are not limited to, dithiolene and phenyldiamine nickel complex types such as shown in Table I.

Table 1 - Examples of IR Selective Dyes for Filter Applications

Chemical Structure	Absorption peak, nm λ_{max}
I Bis(benzene-1,2-dithiolate) nickel complex:	890
	
II. Bis(4-dimethylamino)dithiobenzil) nickel complex:	1070
	
III. Bis(dithiobenzil) nickel complex:	860
	
IV. Phenyl diamine nickel complex:	790
	

One method of forming an IR light selective plastic element is through a molding process such as transfer in molding, injection molding, potted molding, and so forth. IR dyes of the type contemplated by the invention are typically supplied in powder form. Thus, the IR dye(s) is/are combined with plastic resins that themselves are typically supplied in pellet form. Methods of mixing include two-roll mills or a Banbury mixer. After mixing, the combined material is supplied to a mold via a transfer mold process, for example. In one embodiment, the mold is heated to approximately 150 °C, and the material cures for 2-5 minutes.

In one embodiment, silicon, metal, or other material is photolithographically etched and bonded into a mold to provide the desired mold pattern. Other methods such as shaping a mold by diamond turning to make radial patterns or shaping with laser light may also be used.

A second way of forming the IR selective plastic elements contemplated by the invention is by dip coating. In this technique, the IR dye is mixed with a polymer such as poly(methyl methacrylate) or polycarbonate(s). The clearmold package is dipped into a solvent system and withdrawn slowly at a controlled speed. The solvent system can contain one solvent or a mixture of solvents with fast, medium, and slow evaporation rates that provide a smooth and even coating. In one embodiment, the viscosity of the solvent system is in the range of 30-100 mPa-sec. The coated element is then heated to approximately 160°C in the case of a polycarbonate element and 120°C in the case of a poly(methyl methacrylate) element for thirty minutes to remove the solvent.

Table 1 illustrates various dyes having different absorption peaks. In order to provide the desired IR selectivity spectrum, it may be necessary to mix or combine two or more dyes. For an IR coating: An example of a formulation that provides IR selectivity in the range of 650 nanometers to 1,000 nanometers is: 100 parts by weight of polycarbonates, 0.2 parts of bis(dithiobenzil) nickel complex, 0.2 parts of phenyldiamine nickel, and 0.1 parts of (4-dimethylamino dithiobenzil) nickel complex for a coating of 2 mils. For a mold compound application, a formulation of 100 parts by weight of mold compound, 0.01 parts of bis(dithiobenzil) nickel complex, 0.01 parts of phenyldiamine nickel, and 0.005 parts of bis(4-dimethylamino dithiobenzil) nickel complex is appropriate for a clearmold package thickness of one millimeter covering the photosensor array. The formulation may be altered to provide for other thicknesses. (Although the primary function of using nickel complex die is to have IR absorbing properties, the nickel complex IR absorbing dyes were found to be good oxygen quenching agents that prevent oxidation and color fading and aging of plastics.)

The above discussion focused on the inclusion of an IR selective element or filter for use in an image sensing system, such as a camera. In general, applications of such image sensing devices will seek to filter (e.g., reflect or absorb) IR light in the range of 780-1100 nanometers. It is to be appreciated that the element or filter can be made selective to other wavelengths as warranted by the particular application and that the invention should not be limited to elements selective to a specific spectral range. Instead, the principles set forth herein can be applied to applications involving various selectivity concerns.

Figure 10 shows a flowchart of one embodiment for creating a clearmold package having an optical surface. The flowchart starts at block 501, at which a die is placed within a mold. The die is typically attached to a substrate using a die attach with leads extending out of the mold, as is well known. At block 502, a filter material is combined with the mold compound. In one embodiment the filter material is a dye that filters light in the infrared range, however, the filter material is not limited to dyes nor to the particular infrared wavelength range. At block 503, the mold compound is supplied to the mold, heated, and cured to produce a clearmold package having an optical surface. In one embodiment, the optical surface has a stringent surface blemish requirement (e.g., no blemish comparable to the size of a pixel of the photosensor die). The clearmold package with optical surface is used in an imaging system to capture images.

The image sensor 60 and its alternatives described above may be used as part of a digital imaging system 400 shown in Figure 9. Imaging system 400 has an optical system 430 that channels the incident light to create an optical image on image sensor 60. The optical system 430 may include one or more lenses including a zoom capability, or the optical system 430 may include solely the lens formed as part of the clearmold package. Control signal generation logic 418 is provided to generate the reset signals and wordlines needed to control photocells of the image sensor of image sensing device 405. The output values (sensor signals) may be further processed in analog form before being fed to an analog-to-digital A/D conversion unit 410 that in turn feeds digital processing block 414. Analog signal processing, the A/D unit, and portions of the digital processing block may be located on the same die as the sensor array. The digital processing may include hardwired logic and/or a programmed processor that performs a variety of digital functions, including preparing digital image data based on the sensor signals for storage or transmission.

Transmission of the image data to an external processing system may be accomplished using communication interface 424. For instance, as a digital camera, system 400 will contain a communication interface that implements a computer peripheral bus standard such as universal serial bus (USB) or IEEE 1394-1995. Imaging system 400

may also contain local storage 428 of the non-volatile variety, for instance including a solid state memory such as a removable memory card, a rotating magnetic disk device, or other suitable memory device for permanent storage of digital image data. The operation of system 400 may be orchestrated by a system controller 422 which may include a conventional microcontroller responding to instructions stored as firmware.

Thus, an apparatus and method of combining optical functionality with a clearmold package is disclosed. The specific arrangements and methods described herein are merely illustrative of the principles of this invention. Numerous modifications in form and detail may be made without departing from the scope of the described invention. For example, the lens portion of the clearmold surface need not be combined with an anti-aliasing surface; either enhancement may be used alone. Also, although the mold compound is described with reference to classes of plastic, the same concepts can be applied to other transparent compounds. Although this invention has been shown in relation to a particular embodiment, it should not be considered so limited. Rather, the described invention is limited only by the scope of the appended claims.

CLAIMS

WHAT IS CLAIMED IS:

1. An image sensor comprising:
 - a photosensor; and
 - a packaging means associated with the photosensor, the packaging means for directing light to the photosensor.
2. The image sensor of claim 1, wherein the packaging means includes a molded surface for modifying light properties.
3. The image sensor of claim 2, wherein the molded surface is a refractive surface.
4. The image sensor of claim 3, wherein the molded surface includes a pattern that reduces aliasing effects of image capture.
5. The image sensor of claim 4, wherein the packaging means includes an infrared filter.
6. The image sensor of claim 2, wherein the molded surface is a diffractive surface.
7. The image sensor of claim 6, wherein the molded surface includes a pattern that reduces aliasing effects of image capture.
8. The image sensor of claim 7, wherein the packaging means includes an infrared filter.
9. An image sensor comprising:
 - a photosensor die; and
 - a clearmold package encapsulating the photosensor die, the clearmold package having an optical surface that directs an image onto the photosensor die.
10. The image sensor of claim 9, wherein the optical surface is a diffractive surface.

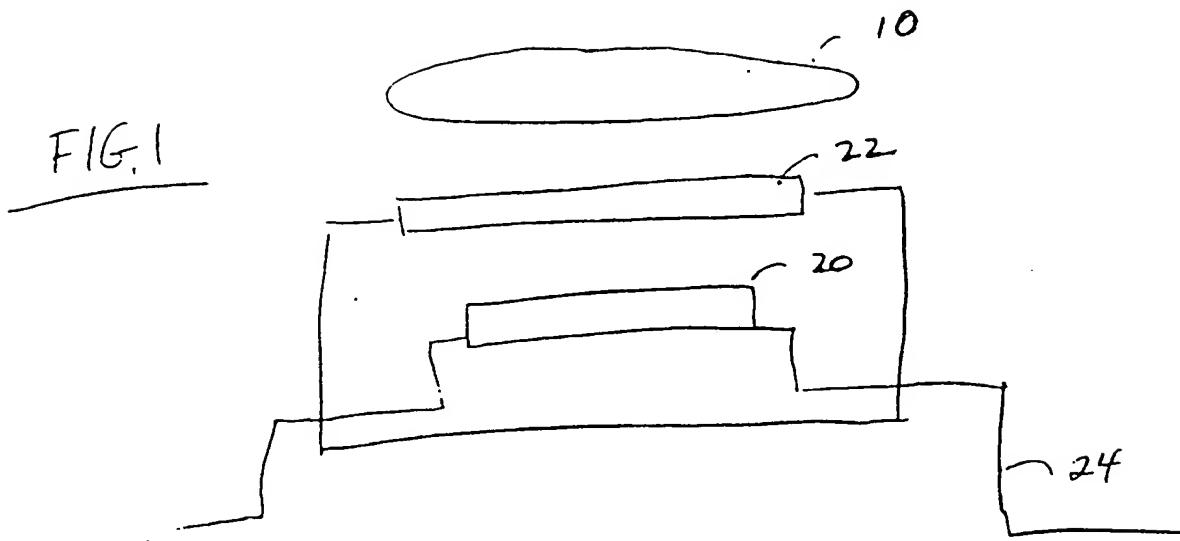
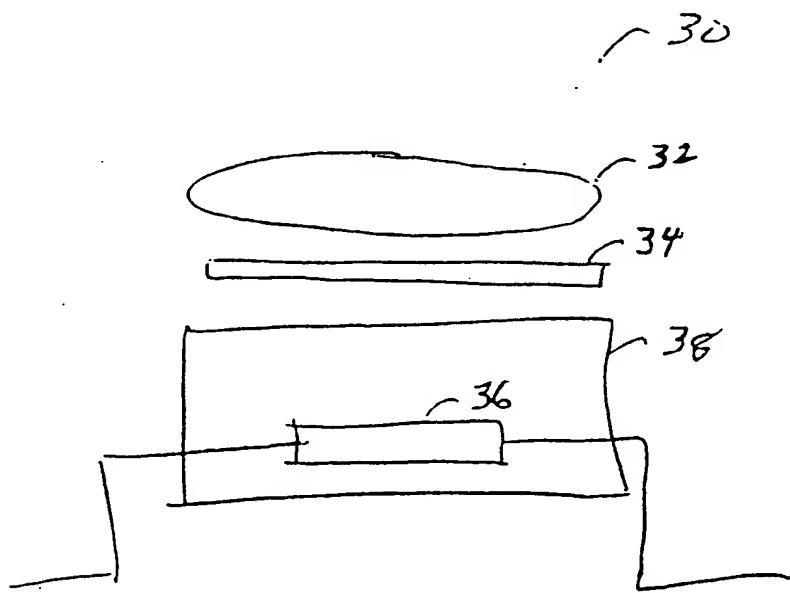
11. The image sensor of claim 10, wherein the optical surface includes a pattern that reduces aliasing effects of image capture.
12. The image sensor of claim 11, wherein the clearmold package is an infrared filter.
13. The image sensor of claim 9, wherein the optical surface is a refractive surface.
14. The image sensor of claim 13, wherein the optical surface includes a pattern that reduces aliasing effects of image capture.
15. The image sensor of claim 14, wherein the clearmold package is an infrared filter.
16. The image sensor of claim 9, wherein the optical surface includes a kinoform structure.
17. The image sensor of claim 9, wherein the optical surface includes a binary optic diffractive structure.
18. The image sensor of claim 9, wherein the optical surface includes a fresnel lens.
19. A method comprising:
placing a die having a photosensor array in a mold; and
supplying a mold compound into the mold to produce a clearmold package
having a lens to focus light onto the photosensor array.
20. The method of claim 19 further comprising:
capturing an image with the photosensor array.
21. The method of claim 19 further comprising:
coating the lens to provide an infrared filter.
22. The method of claim 19 wherein the supplying the mold compound into the mold further comprises transferring the mold compound into a mold having formed thereon a diffractive pattern.

23. The method of claim 22 further comprising:
adding a dye to the mold compound to block certain wavelengths of light from being transmitted.
24. The method of claim 23 further comprising:
adding an infrared filter to the mold compound.
25. The method of claim 19 wherein the supplying the mold compound into the mold further comprises transferring the mold compound into a mold having formed thereon a refractive pattern.
26. The method of claim 25 further comprising:
adding a dye to the mold compound to block certain wavelengths of light from being transmitted.
27. The method of claim 26 further comprising:
adding an infrared filter to the mold compound.
28. A method comprising:
placing a die having a photosensor array in a mold; and
transferring a mold compound into the mold to produce a clearmold package having a pattern that reduces aliasing effects on images captured by the photosensor array.
29. The method of claim 28 further comprising:
capturing an image with the photosensor array.
30. The method of claim 28 further comprising:
coating a surface of the clearmold package to provide an infrared filter.
31. The method of claim 28 further comprising:
adding a dye to the mold compound to filter certain wavelengths of light.
32. The method of claim 28 further comprising:
adding a dye to the mold compound to filter infrared light.

33. An imaging system comprising:
 - a clearmold package having an optical surface to focuses an image onto a photosensor array encapsulated within the clearmold package, the clearmold package providing an image output; and
34. The imaging system of claim 33 further comprising:
 - an A/D converter to process the image output and convert the image output to a digital output; and
 - a digital processor coupled to receive the digital output and provide image data to a communication interface.
35. The imaging system of claim 33, wherein the clearmold package has an anti-aliasing surface.
36. The imaging system of claim 35, whercin the clearmold package has an infrared filter.

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FIG. 1FIG. 2

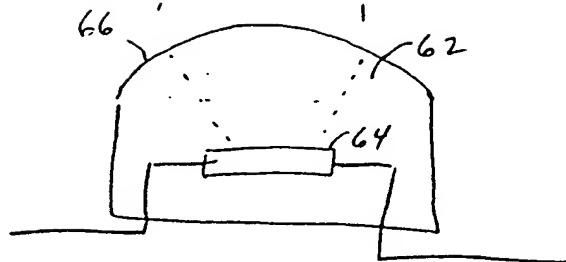
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FIG. 4A

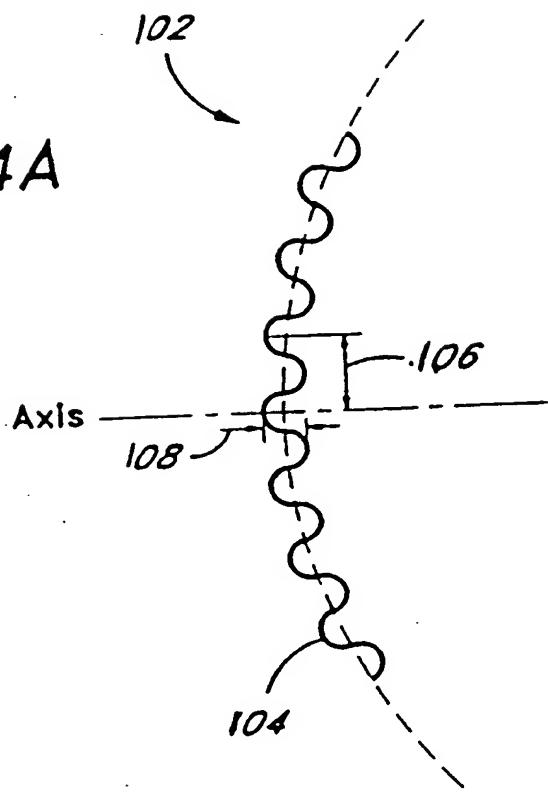


FIG. 4B

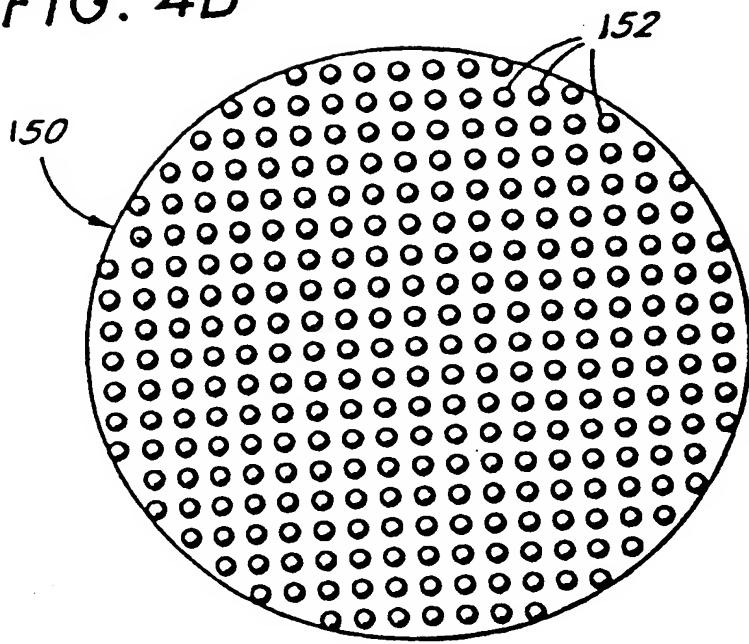


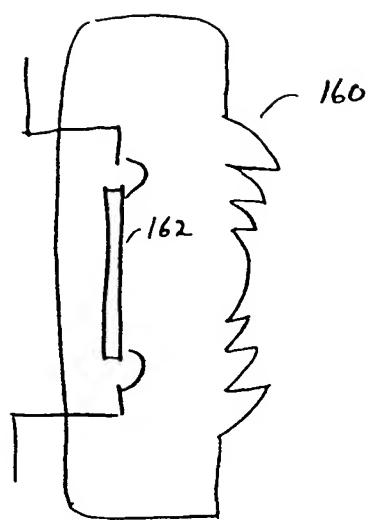
FIG 5

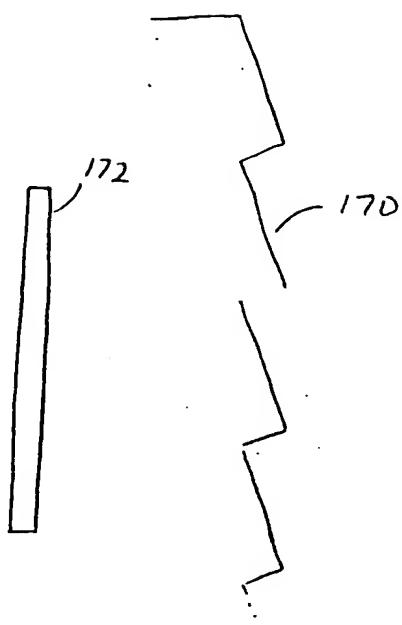
FIG 6

FIG. 7A

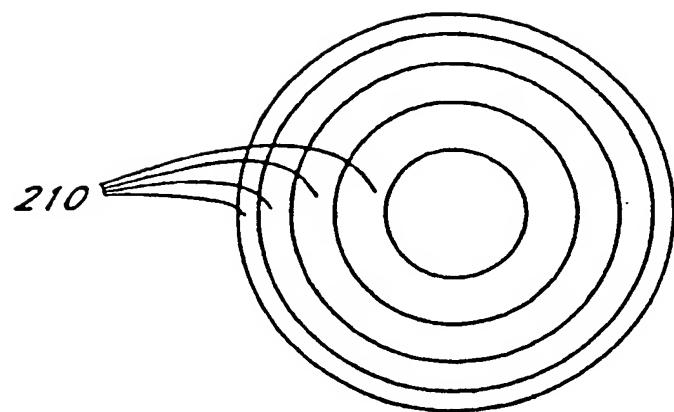


FIG. 7B

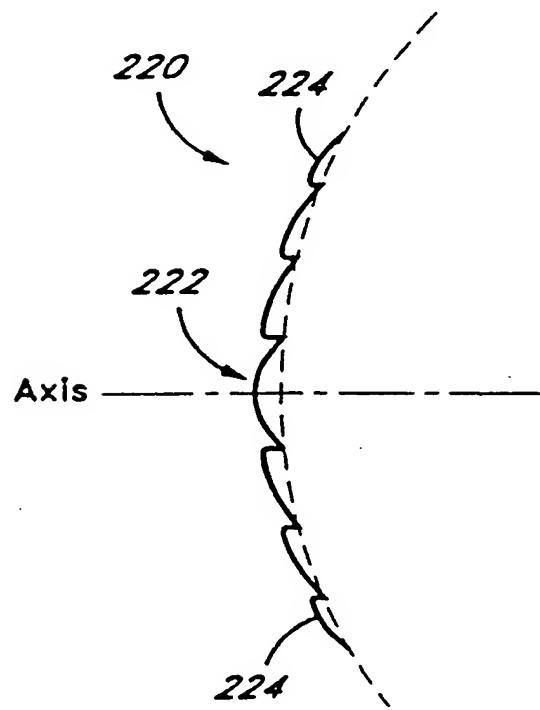
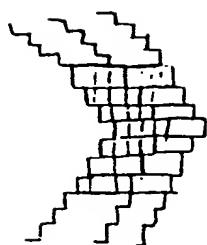
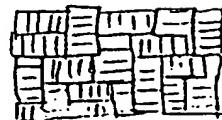


FIG. 8BFIG. 8C

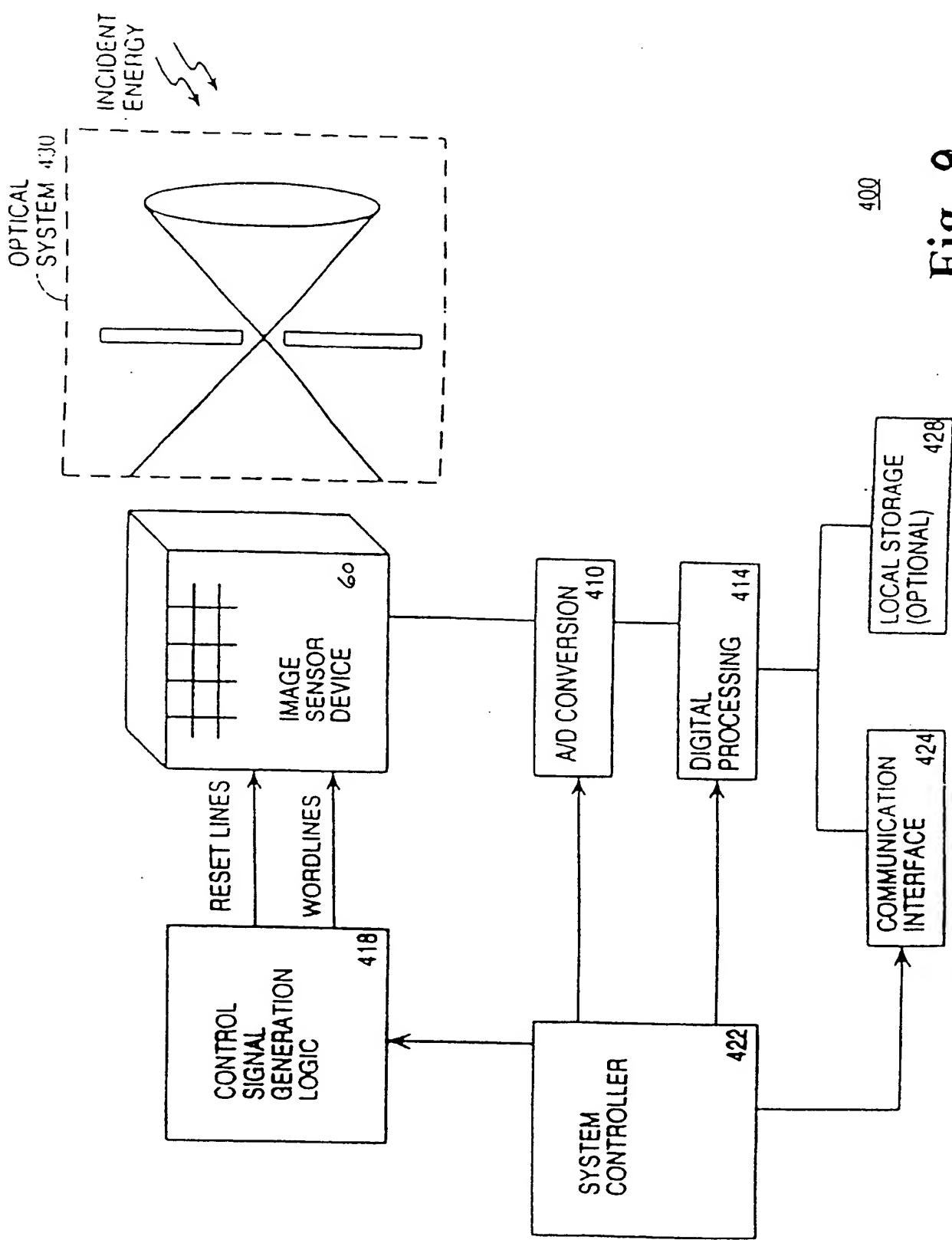


Fig. 9

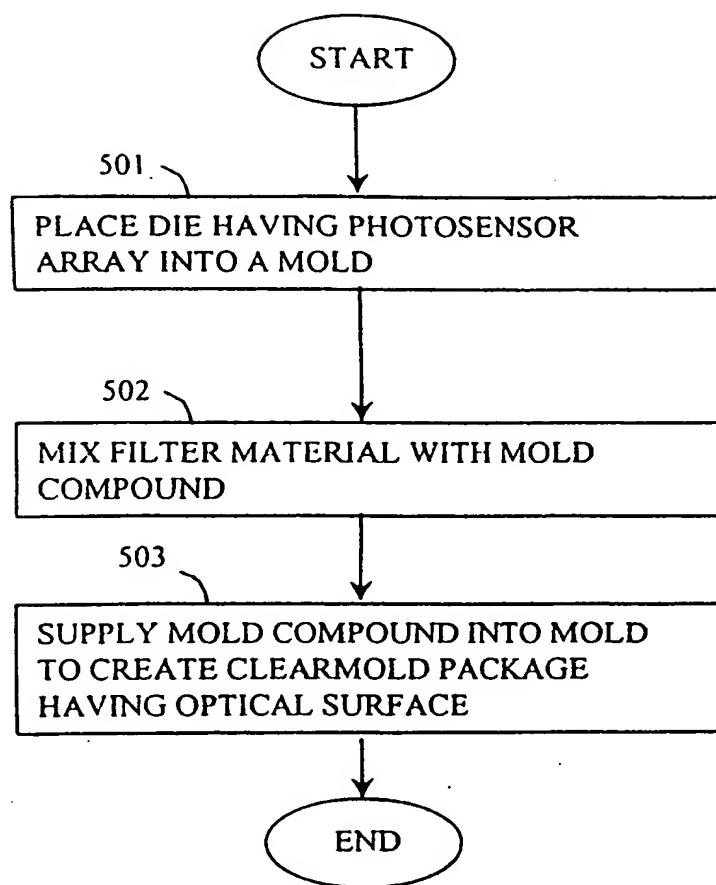


FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/29167

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01L31/0232

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 130 531 A (ITO YOSHINORI ET AL) 14 July 1992 (1992-07-14)	1-3, 9, 13, 18-20, 25, 28, 29, 33 4-8, 10-12, 14, 15, 17, 21, 22, 29, 35, 36
Y	column 7, line 64 -column 8, line 68; figure 6 ---- -/-	

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
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- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

28 April 2000

Date of mailing of the international search report

10/05/2000

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/29167

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 283 691 A (OGASAWARA YUJI) 1 February 1994 (1994-02-01) column 3, line 13 - line 21 column 4, line 29 - line 47 column 5, line 47 - line 52; figures 2,4 —	4-8, 10-12, 14,15, 17,21, 22,29, 35,36
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A	EP 0 253 664 A (CANON KK) 20 January 1988 (1988-01-20) column 5, line 60 -column 6, line 12; figures 3,12 —	1,5,8,9, 12,15, 19,24, 28,30, 33,36
A	DE 41 04 055 A (HONEYWELL INC) 6 November 1997 (1997-11-06) page 3, line 2 - line 10; figure 3 —	16

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Docket # Q003P13771

Applic. #

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